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MONTANA DEPARTMENT
OF
NATURAL RESOURCES AND CONSERVATION

WATER RESOURCES DIVISION

TONGUE RIVER PROJECT

MODIFICATION FEASIBILITY STUDY
SUMMARY

APRIL 1977

R.C. HARLAN AND ASSOCIATES

consulting engineers

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MONTANA DEPARTMENT

OF

NATURAL RESOURCES AND CONSERVATION

WATER RESOURCES DIVISION

TONGUE RIVER PROJECT

MODIFICATION FEASIBILITY STUDY

SUMMARY

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Richard C. Harlan

APRIL 1977

R.C. HARLAN AND ASSOCIATES

consulting engineers

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I SUMMARY

In southeastern Montana additional water is needed for irrigation and municipal water supply. There are extensive deposits of coal presently being developed in this area by the energy industry and additional water supplies are also needed to make optimum use of this natural energy resource. The Tongue River Project is intended to provide additional water for use by agriculture, municipalities and industry in southeastern Montana.

The spillway of the existing Tongue River Dam is inadequately sized to pass the probable maximum flood. Also, the spillway is in deteriorated condition and urgently needs replacement to provide for the safety of the reservoir. The potential failure of the Tongue River Dam would be a disaster to southeastern Montana. Not only heavy property loss would ensue but lives could be lost. The present dependable water supply would be gone for many years while the dam is reconstructed and the reservoir refilled. Loss of water supply would create great consequential financial loss to agriculture in the area.

This summary report presents alternative designs and cost estimates for enlarging the Tongue River Irrigation Reservoir including rebuilding the spillway and raising the existing Tongue River Dam. The alternatives are compared with an updated cost estimate for the High Tongue River Dam previously proposed for construction downstream from the existing dam. Also included are preliminary designs (and cost estimates) for correcting the existing Tongue River Dam Outlet Works. We conclude that it is technically feasible to increase the storage in Tongue River Reservoir by raising the existing Tongue River Dam up to Elevation 3465 or by constructing the proposed High Tongue River Dam downstream.

Nine alternatives for modifying the Tongue River Dam along with an updated cost esimtate (Alternative 6) for the Stage I High Tongue River Dam are compared in the following table. Alternatives 1 through 5 are for modifying and raising the existing

reservoir without using crest gates on the spillway. Alternatives 7 through 10 include the use of spillway crest gates. The costs are based on beginning project design in 1977 and include engineering geotechnical investigation and surveys, construction of dam, spillway and outlet works, resident engineering during construction, and contingency allowance but do not include land, land rights, State of Montana administration, environmental investigation and reports, financing and interest costs, or escalation for delay in project start beyond 1977.

Alternative	Comparative Cost	Total Firm Yield Water Supply Acre Feet Per Year	Increase in Firm Yield Water Supply Acre Feet Per Year
1. Modify Dam, Spillway and Outlet Works at Present Storage Elev. 3424.4	$ 30,112,000	42,000	--
2. Modify Dam, Spillway and Outlet Works to Storage Elev. 3438	33,437,000	67,500	25,500
3. Modify Dam, Spillway and Outlet Works to Storage Elev. 3465	33,890,000	100,000	58,000
4. Raise Modified Storage Elev. of 3424.4 to 3438	5,695,000 (1)		
Raising Cost plus Alternative 1 Cost	35,807,000	67,500	25,500
5. Raise Modified Storage Elev. of 3438 to 3465	8,751,000 (2)		
Raising Cost plus Alternative 2 Cost	42,188,000	100,000	58,000
6. Construct Stage I High Tongue River Dam downstream to Elev. 3438	63,501,000	100,000	58,000
7. Modify Dam, Existing Structures, Spillway at Storage Elev. 3424.4 with Future Gate Provisions	34,999,000	42,000	--
8. Modify Existing Reservoir to Storage Elev. 3438 with Future Gate Provisions	34,471,000	67,500	25,500

(1) Additional amount to be added to Alternative 1 for Total Comparative Cost.

(2) Additional amount to be added to Alternative 2 for Total Comparative Cost.

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Alternative	Comparative Cost	Total Firm Yield Water Supply Acre Feet Per Year	Increase in Firm Yield Water Supply Acre Feet Per Year
9. Raise Existing Reservoir from Elev. of 3424.4 to 3438 with Provision for Future Gates	3,479,000 (3)		
Raising Cost plus Alternative 7 Cost	38,478,000	67,500	25,500
10. Raise Existing Reservoir from Elev. of 3438 to 3465 by Provision of Gates	1,653,000 (4)		25,500
Raising Cost plus Alternative 8 Cost	36,124,000	100,000	58,000
Raising Cost plus Alternatives 7 and 9 Costs	40,131,000	100,000	58,000

(3) Additional amount to be added to Alternative 7 for Total Comparative Cost.

(4) Additional amount to be added to Alternative 8 and Alternatives 7 plus 9 for Total Comparative Costs. Alternative 10 requires less land than alternatives 3 and 5 because of the lower flood water elevation possible with a gated spillway.

These estimates do not include costs for land and land rights, State of Montana administrative costs, environmental investigations and reports, interest and costs of financing and escalation to beginning of project.

II INTRODUCTION

This summary report presents feasibility level modification designs and cost estimates for the existing Tongue River Dam. The purpose of these designs and cost estimates is to provide the Montana Department of Natural Resources and Conservation with data to make decisions with regard to alternatives to the proposed High Tongue River Dam. Included are plans for replacing the existing inadequate spillway and modifying the dam to pass the probable maximum flood safely, along with correction of the outlet works. Also included are designs for incremental raising from the present reservoir storage level of 3424.4 to elevations of 3438 and 3465. Storage elevation 3438 allows for about 3.5 feet of freeboard before water is backed across the state line into Wyoming and is the same elevation as the spillway for the High Tongue River Dam. Storage elevation 3465 at the existing site provides sufficient storage capacity to give the same firm yield as the High Tongue River Dam. Each of these raising plans includes the appropriate spillway and dam modification changes, improvements to the seepage control for the reservoir as considered appropriate on the basis of present information, and modification plans for the existing outlet works. Alternatives 1 through 5 are for spillways without crest gates. Alternatives 7 through 10 are for gated spillways. Also included is an updated cost estimate for the proposed High Tongue River Dam, Stage 1, on the basis of the design presented in the Bechtel, Inc. Basic Design Report of 1969, Alternative 6.

This summary report presents designs and cost estimates which supplement those presented in the Modification Feasibility Report of October 1976. Four additional alternatives, numbers 7 through 10, were developed to provide for the use of spillway crest gates in staged raising. Also included in this report is a summary of the cost estimates presented in the October 1976 report, revised where indicated.

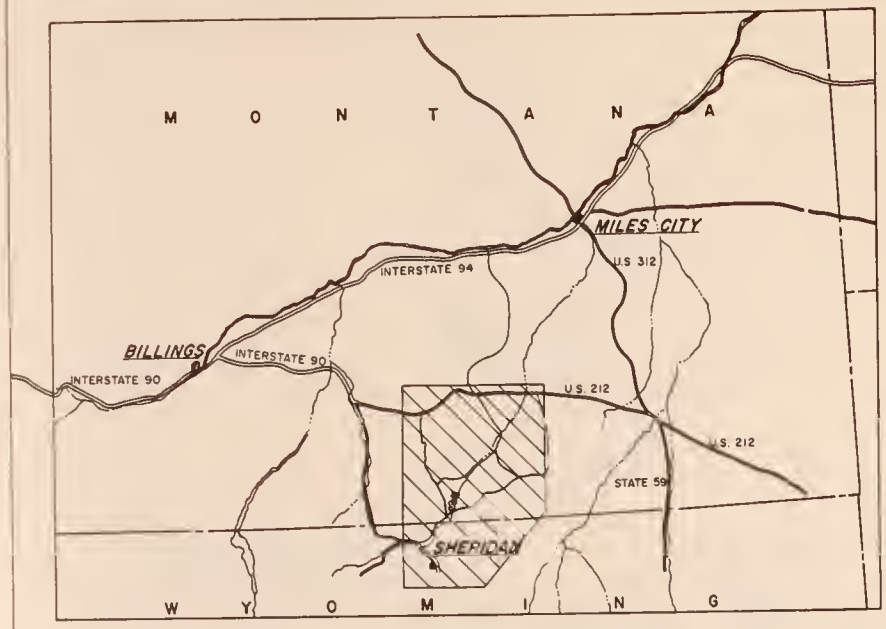
Included in this summary report are plans for replacing the existing inadequate spillway and modifying the dam to pass the probable maximum flood safely. Also included are designs for incremental raising from the present reservoir storage level of 3424.4 to elevations of 3438 and 3465. The final stage of raise to 3465 with these additional alternatives includes raising the water storage elevation by installing crest gates on the spillway without raising the dam embankment. Each of these raising plans includes the appropriate spillway and dam modification changes, improvements to the seepage control for the reservoir and modification plans for the existing outlet works, all similar to those included in the referenced report.

The referenced report included a description of the Tongue River system, the history of water use, water supply studies and flood hydrology, geology of the dam site and construction materials. Additional flood routing studies were made for the supplementary studies to provide for the different configuration of spillway which includes a provision of piers to support crest gates.

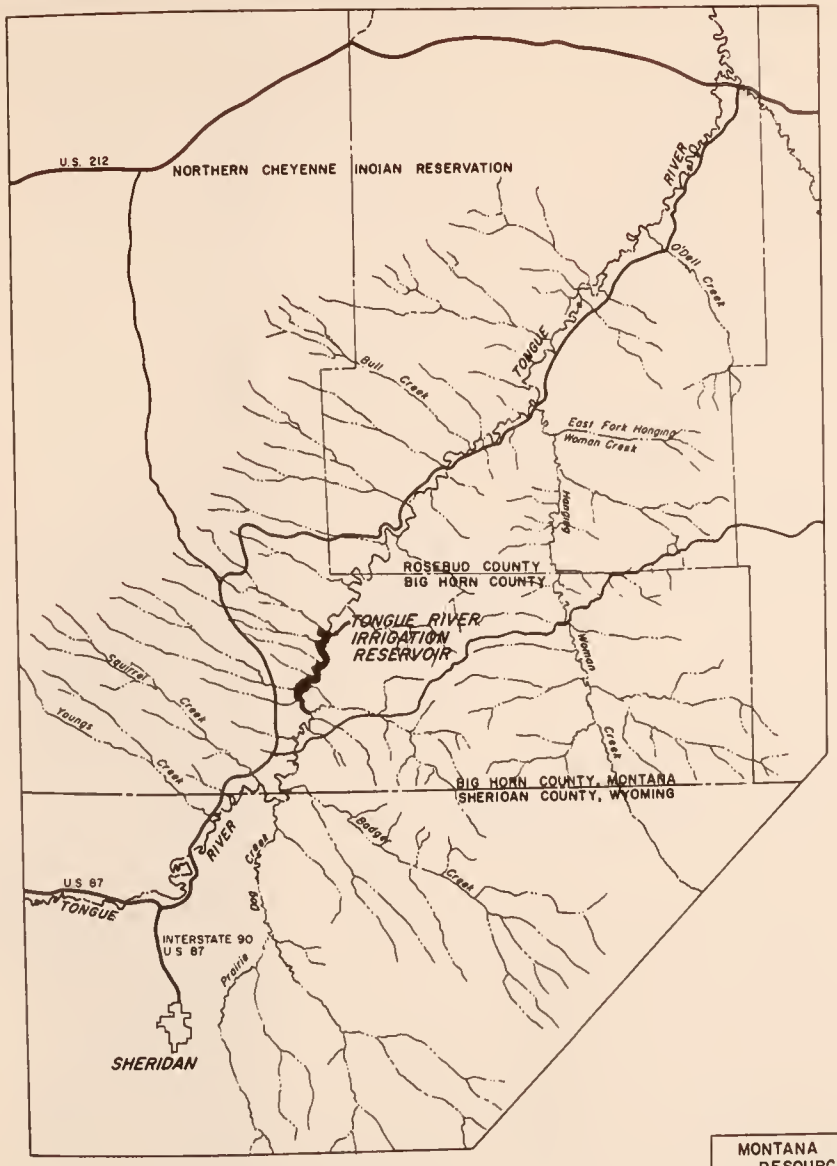
Tongue River water has been used for domestic and irrigation purposes since the late 1800's. In 1939, the Montana State Water Conservation Board constructed the Tongue River Dam which impounds the Tongue River Irrigation Reservoir for irrigation and other beneficial uses. The Tongue River Irrigation Reservoir is located on the Tongue River north of Decker, Montana, and is the major storage reservoir in the Tongue River Basin.

The location and vicinity maps for the Tongue River Project are shown on Figure 1. A reservoir map showing the extent of the water surface elevations and flood surcharge elevations for each of the alternatives is shown on Figure 2.

The scope of these studies is limited to the use of the design criteria and data contained in the reports prepared by Bechtel.



LOCATION MAP



VICINITY MAP TAKEN FROM AMS SHEET, HARDIN NL 13-7 SHERIDAN NL 13-10

VICINITY MAP

5 0 5 10 15

MILES

MONTANA DEPARTMENT OF NATURAL RESOURCES AND CONSERVATION
WATER RESOURCES DIVISION

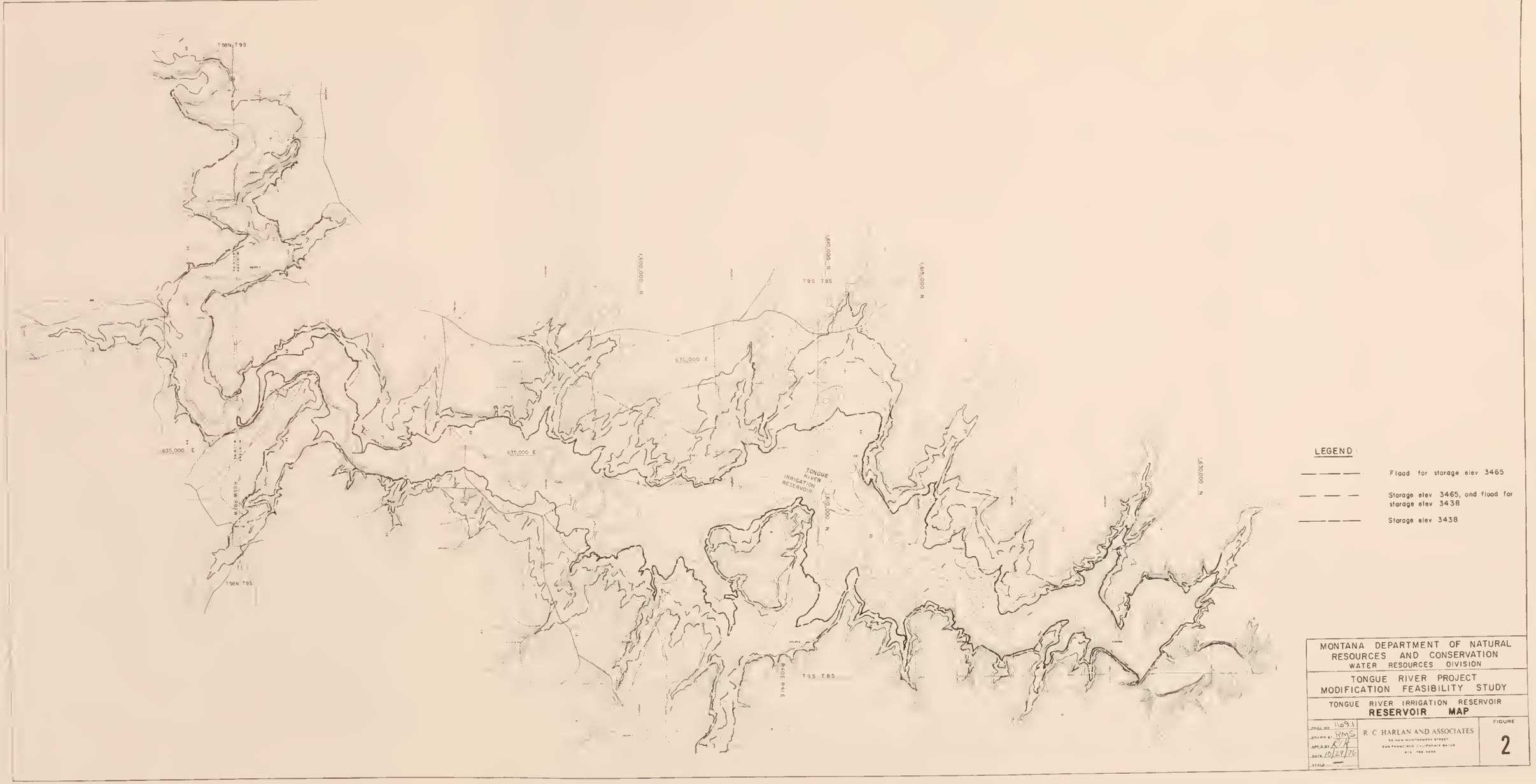
TONGUE RIVER PROJECT
MODIFICATION FEASIBILITY STUDY

LOCATION AND VICINITY MAPS

PROJ. NO. 169.1
DRAWN BY RMS
APP'D BY RH
DATE 10/29/76
SCALE As Shown

R C. HARLAN AND ASSOCIATES
88 NEW MONTGOMERY STREET
SAN FRANCISCO, CALIFORNIA 94105
(415) 781-6000

FIGURE 1


T58N T9S
635,000 E
636,000 E
N 000'000'
N 000'010'
N 000'020'
T9S T8S
TONGUE RIVER IRRIGATION RESERVOIR
RAGE PAILE
LEGEND
Flood for storage elev 3465
Storage elev 3465, and flood for storage elev 3438
Storage elev 3438
MONTANA DEPARTMENT OF NATURAL RESOURCES AND CONSERVATION
WATER RESOURCES DIVISION
TONGUE RIVER PROJECT
MODIFICATION FEASIBILITY STUDY
TONGUE RIVER IRRIGATION RESERVOIR
RESERVOIR MAP
PROJ. NO 1169.1
DRAWN BY RMS
APP. D BY RCH
DATE 10/29/76
SCALE —
R C HARLAN AND ASSOCIATES
FIGURE
2

In 1967, the Montana Water Resources Board retained Bechtel, Incorporated to prepare a study on the feasibility of obtaining additional water supplies from the Tongue River in Southeastern Montana. The results of these studies are presented in the "Basic Design Report for the Tongue River Project" by Bechtel, Incorporated, dated 1969. That report, which included a volume of supporting data, provided the basic information and criteria used in this modification feasibility study. The results of the firm yield studies included in that 1969 report are summarized as follows:

Alternative	Storage Capacity Acre Feet	Firm Yield Acre Feet Per Year
Existing Tongue River Dam Storage El. 3424.4	68,000	42,000
Raise Existing Tongue River Dam to Storage El. 3438	130,000	67,500
Raise Existing Tongue River Dam to Storage El. 3465	320,000	100,000
High Tongue River Dam Storage El. 3438	320,000	100,000

Another Bechtel study, designated "Water Allocation Study," presented information on the allocation of the Tongue River water between the State of Wyoming and Montana under the Yellowstone River Compact. The "realistic" allocation of water developed by Bechtel in their studies was used as a basis for their determinations of firm yield of the Tongue River Basin. Due to the extent of the information, basic data and design criteria collected and developed in those reports, it is considered that they provide sufficient basis for these modification feasibility studies. Additional information has been provided by the Montana Water Resources Division staff. Summaries of data contained in the Bechtel reports on hydrology, geology and construction materials, have been included in the Appendix of the October 1976 report to provide basic background information.

The Bechtel reservoir area capacity and yield curves are presented on the following pages. A detailed chronology of the Bechtel studies carried out in 1967-1969 is presented in the Appendix to the October 1976 report for reference.

In 1975, the Montana Legislature authorized the Montana Department of Natural Resources and Conservation to study further alternatives of raising the storage elevation of the existing Tongue River Dam. On September 8, 1976, the Department authorized R. C. Harlan and Associates to carry out the modification studies and cost estimates presented in the October 1976 report. On February 24, 1977, the Department authorized the work presented in this summary report.

The following persons participated in these Modification Feasibility Studies:

Montana Department of Natural Resources
and Conservation
Water Resources Division

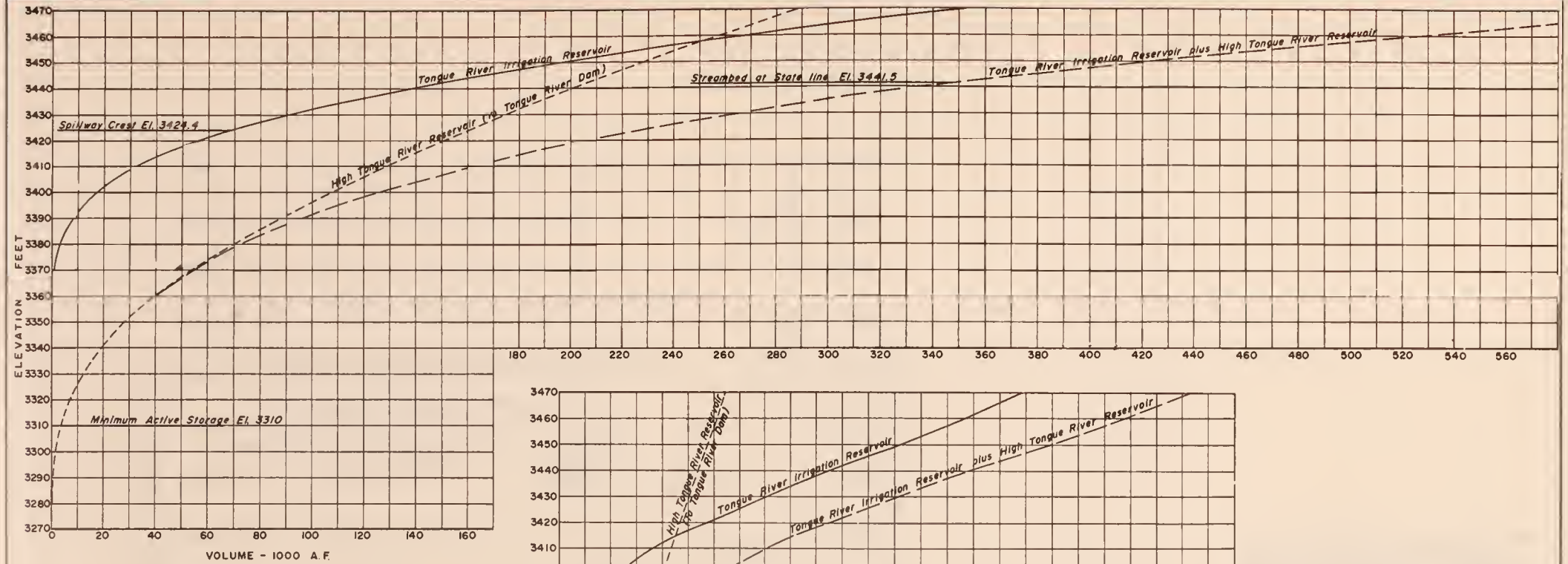
Orrin Ferris, Administrator
Richard Bondy, Chief Engineer
Robert Clark, Project Engineer

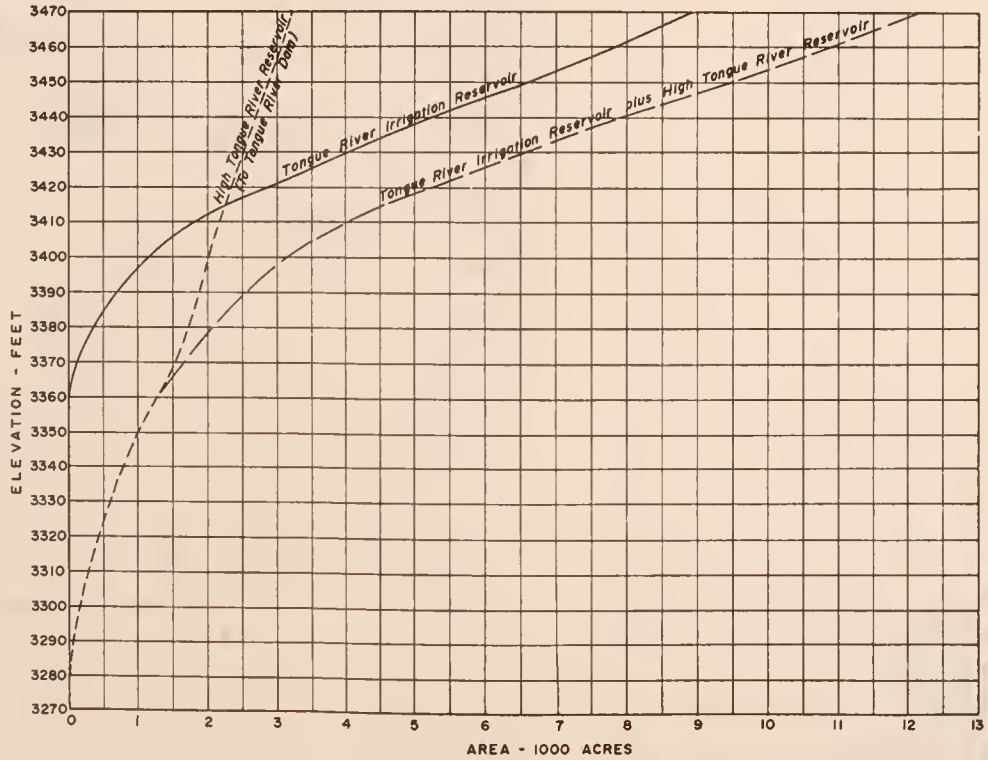
R. C. Harlan and Associates

Richard C. Harlan, Project Manager
Robert H. York, Project Engineer,
Dams and Spillways
Richard G. Tait, Project Engineer,
Outlet Works Modifications
John N. Carver, Project Engineer,
High Tongue River Dam Estimate

Consultants

Herbert S. Riesbol, Hydrology and Hydraulics
Frank G. Bystrowski, Construction Costs
and Schedules - October 1976 report





MONTANA
J. GEORGE THON
1850 E
PROFESSIONAL ENGINEER

NO	DATE	REVISIONS	BY	BY	PROJ. ENG'R	MGR SP PROJ	MGR ENG'R

WATER SUPPLY STUDIES
RESERVOIR AREA AND CAPACITY

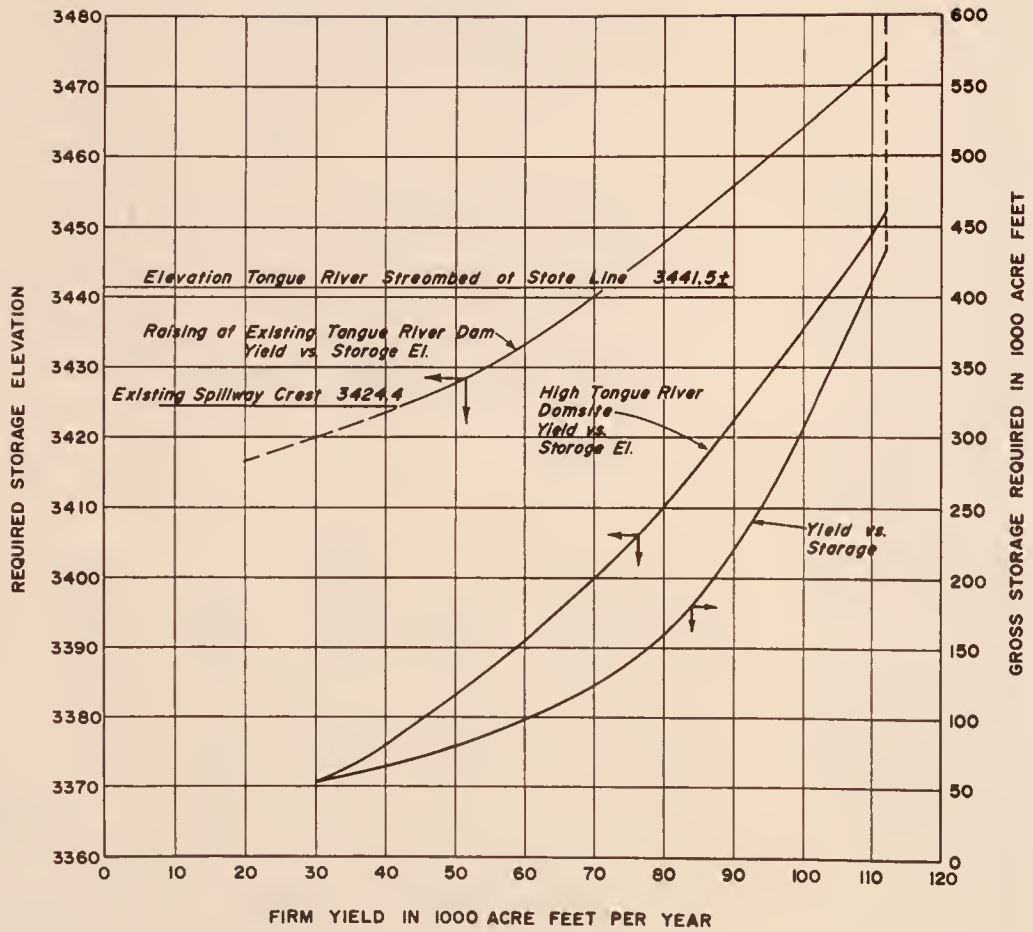
TONGUE RIVER PROJECT
MONTANA WATER RESOURCES BOARD
HELENA, MONTANA

APPROVED _____ DATE _____

BECHTEL CORPORATION
SAN FRANCISCO

DESIGNED _____ PROJ ENG'R RCH
DRAWN SHIMADA MGR SP PROJ RVT
CHECKED RMS MGR ENG'R

JOB No.	DRAWING No.	REV.
6694	6694 - III - 002	



Firm yield and storage requirements based on Minimum Storable Inflow - Realistic Allocation Study - Downstream Releases 342 cfs Irrigation and 75 cfs winter flow.

MONTANA J. GEORGE THON 1850 E PROFESSIONAL ENGINEER

NO	DATE	REVISIONS	BY	BY	PROJ. ENGR.	MGR. SP. PROJ.	MGR. ENGR.

WATER SUPPLY STUDIES
YIELD - STORAGE - STORAGE ELEVATION

TONGUE RIVER PROJECT
MONTANA WATER RESOURCES BOARD
HELENA, MONTANA

APPROVED _____ DATE _____

BECHTEL CORPORATION
SAN FRANCISCO

DESIGNED _____ PROJ ENGR. RCK
DRAWN SHIRAOKA MGR SP PROJ KUT
CHECKED RAS MGR ENGR. _____

JOB No.	DRAWING No.	REV.
6694	6694 - III - 003	

III DESIGN

The dam embankment designs are based on the same provisions for seepage control, construction materials and geology as were presented in the referenced report and these designs are shown on the attached drawings. The basic data for the preliminary design of the embankments is the same as those presented in Section VII of the referenced report.

The spillway design is based on a modified crest of the spillway utilizing piers for support of crest gates; therefore different flood routing studies were performed since the discharge capability of the spillway is reduced by the presence of the piers. The spillway was maintained, however, at the same 250 foot width as this width appears to be relatively economical and provides for downstream velocities which are tolerable upon exit from the stilling basin. A table summarizing the spillway flood routing studies follows:

Total Length of Spillway Crest is 250 Feet for All Cases

Alternative	Spill. Crest Elev.	Avrg. Disch. Coeff. C	Peak Disc. (cfs)	Flow Depth Peak Disch. (ft)	Max. WS Elev.	Freeboard (ft)	Dam Crest Elev.
7	3424.4	3.4*	111,000	28.9	3453.3	2.7	3456
8	3438	3.9**	102,000	25.0	3463.0	13.0	3476
9	3438	3.9**	102,000	25.0	3463.0	13.0	3476
10	3438 with Gates to 3465	3.9**	184,000	35.0	3473.0	3.0	3476

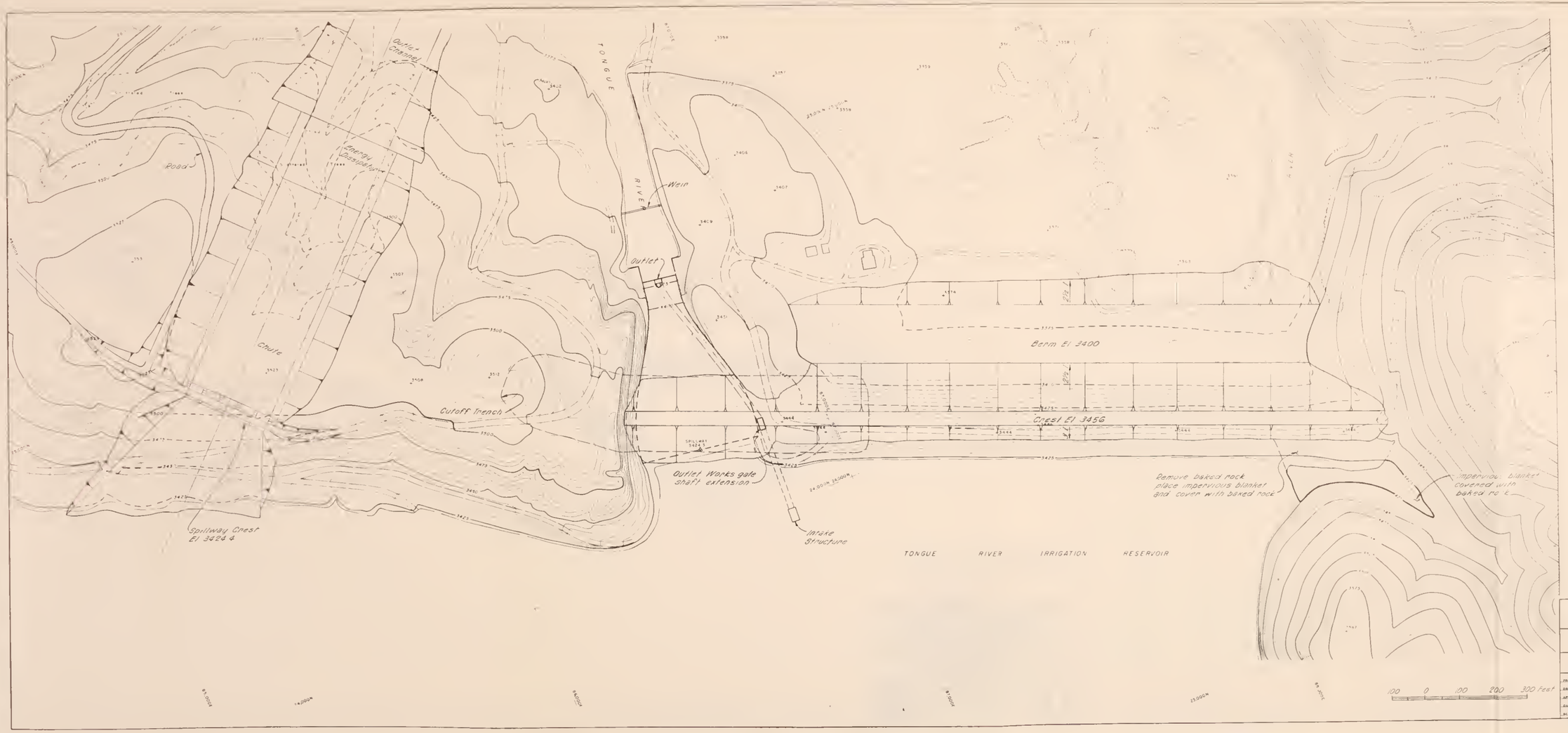
* Average discharge coefficient for the low profile, less hydraulically efficient spillway crest designed for subsequent raising.

** Average discharge coefficient for high profile ogee crest.

The spillway crest structure is designed to facilitate raising the storage elevation from 3424.4 to 3438 by modification of the ogee crest structure and from 3438 to 3465 by the addition of crest gates. The spillway bridge would be installed at the ultimate height with a bridge deck elevation at 3480.

The typical pier and crest gate configuration are shown on the drawings enclosed with this report. Other spillway design features including the stilling basin, raising of the weir, drainage and excavation are the same as those in the referenced report.

The outlet works configuration for this present design is similar to those contained in the referenced report and no further description is included herein.



NOTE
GRID IS BASED ON LOCAL COORDINATE SYSTEM
FIELD SURVEY CONTROL BY R W TOWILL CORP
ELEVATIONS ARE BASED ON MEAN SEA LEVEL DATUM 1929 ADJ

NOTE
IN OPEN UNOBSTRUCTED AREAS THIS MAP COMPLIES WITH NATIONAL STANDARDS FOR MAP ACCURACY

IN AREAS OF DENSE VEGETATION WHERE THE GROUND IS OBSCURED FROM VIEW CONTOURS MAY DEVIATE FROM CORRECT ELEVATION BY ONE HALF THE HEIGHT OF THE COVER

ALTERNATIVE 7

MONTANA DEPARTMENT OF NATURAL RESOURCES AND CONSERVATION
WATER RESOURCES DIVISION

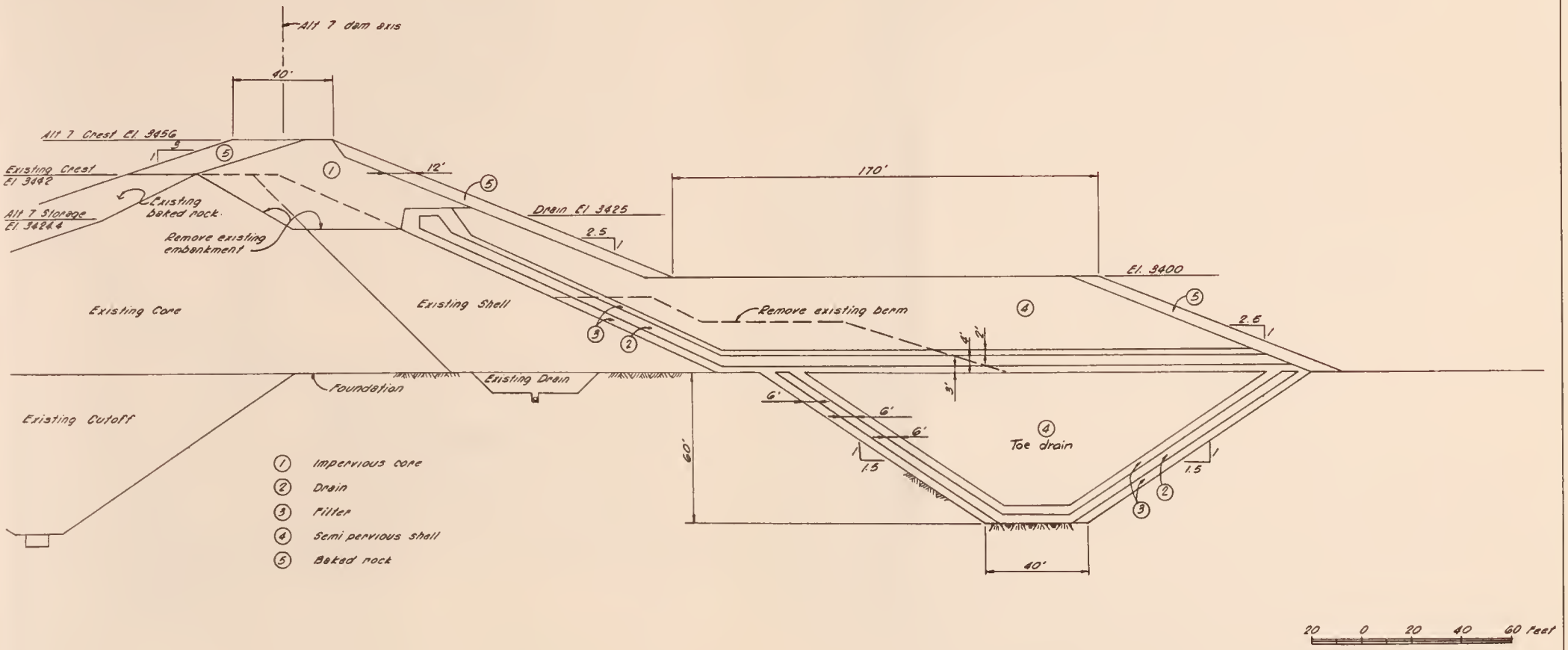
TONGUE RIVER PROJECT
MODIFICATION FEASIBILITY STUDY

STORAGE ELEVATION 3424.4
GENERAL PLAN

PROJ NO 1693
DRAWN BY Ray Rivas
APP'D BY
DATE 8/9/77
SCALE As Shown

R. C. HARLAN AND ASSOCIATES
88 NEW MONTGOMERY STREET
SAN FRANCISCO CALIFORNIA 94105
(415) 768-1688

FIGURE
16



ALTERNATIVE 7

MONTANA DEPARTMENT OF NATURAL RESOURCES AND CONSERVATION
WATER RESOURCES DIVISION

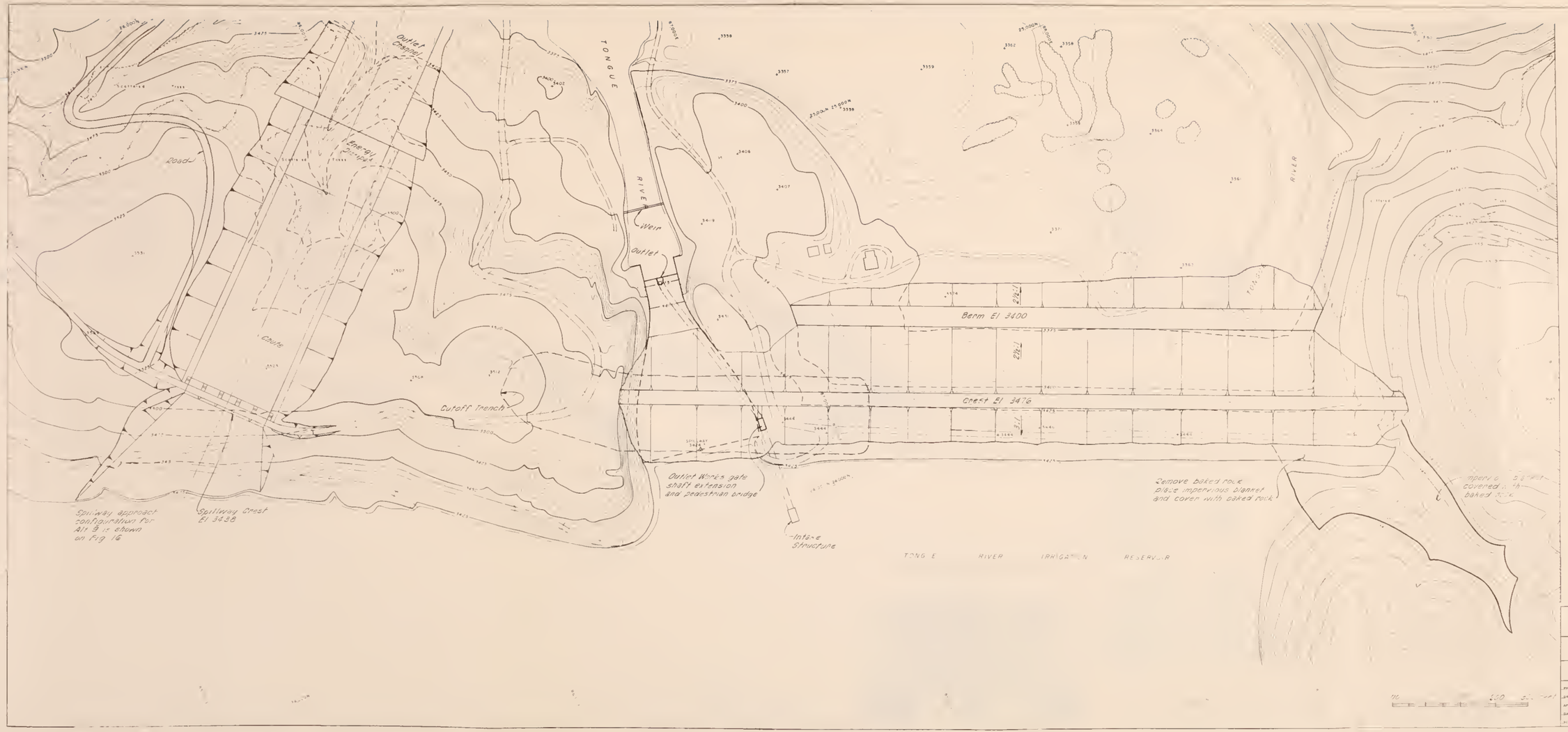
TONGUE RIVER PROJECT
MODIFICATION FEASIBILITY STUDY

STORAGE ELEVATION 3424.4
EMBANKMENT SECTION

PROJ. NO. 169.2
DRAWN BY RHY / RMG
APP'D BY RCH
DATE 4/19/77
SCALE As Shown

R. C. HARLAN AND ASSOCIATES
90 NEW MONTGOMERY STREET
SAN FRANCISCO, CALIFORNIA 94105
(415) 956-4095

FIGURE 17



NOTE
GRID IS BASED ON LOCAL COORDINATE SYSTEM
FIELD SURVEY CONTROL BY M W TOWILL CORP
ELEVATIONS ARE BASED ON MEAN SEA LEVEL DATUM 1929 ADJ

NOTE
IN OPEN UNOBSTRUCTED AREAS, THIS MAP COMPLIES WITH NATIONAL STANDARDS FOR MAP ACCURACY
IN AREAS OF DENSE VEGETATION WHERE THE GROUND IS OBSCURED FROM VIEW, CONTOURS MAY DEVIATE FROM CORRECT ELEVATION BY ONE HALF THE HEIGHT OF THE COVER

ALTERNATIVE 8,9 AND 10

MONTANA DEPARTMENT OF NATURAL RESOURCES AND CONSERVATION
WATER RESOURCES DIVISION

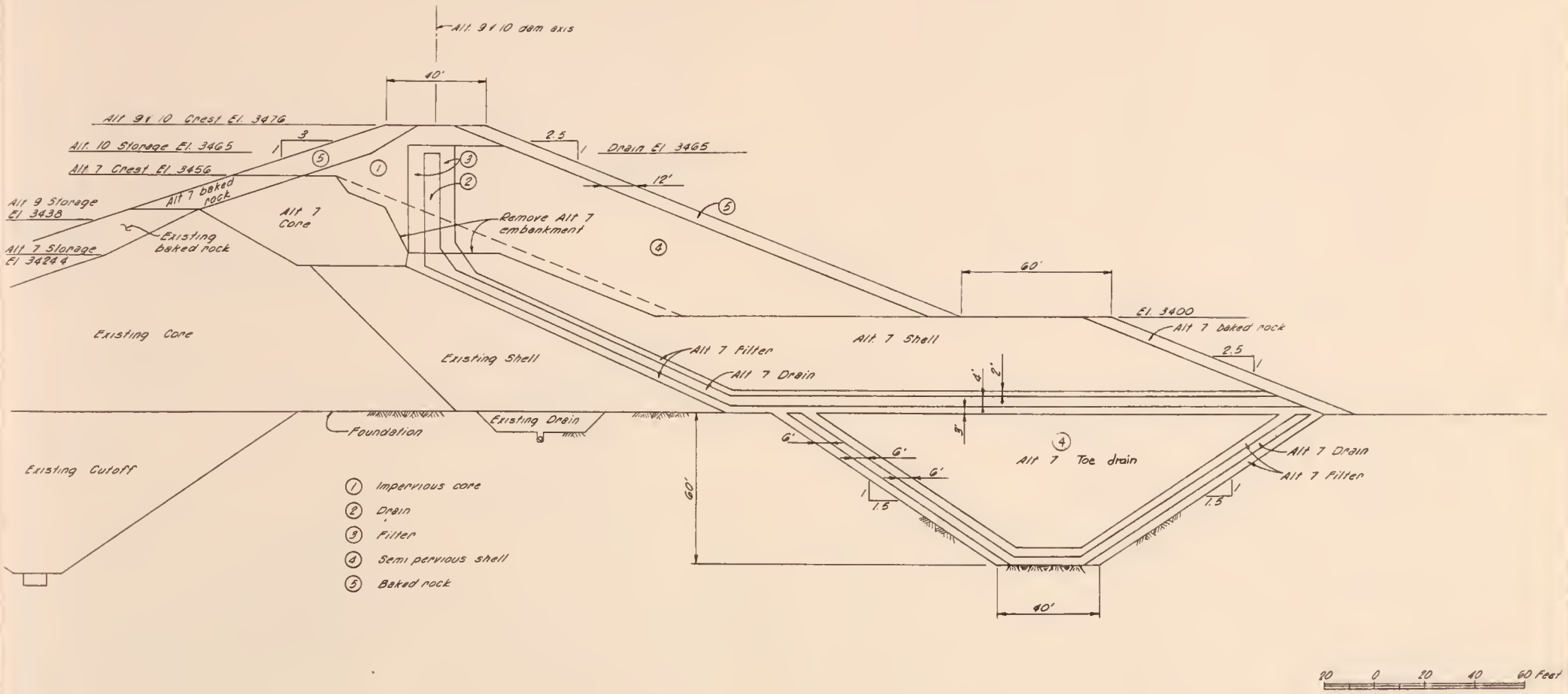
TONGUE RIVER PROJECT
MODIFICATION FEASIBILITY STUDY

STORAGE ELEVATION 3465
GENERAL PLAN

PROJ. NO. 1671
DRN. RMS
DSGN. BY. RMS
APP. BY. RCH
DATE 4/13/77
SCALE As Shown

R C HARLAN AND ASSOCIATES
53 NEW MONTGOMERY STREET
SAN FRANCISCO, CALIFORNIA 94105
(415) 788-4455

FIGURE
18



ALTERNATIVE 9 AND 10

MONTANA DEPARTMENT OF NATURAL RESOURCES AND CONSERVATION
WATER RESOURCES DIVISION

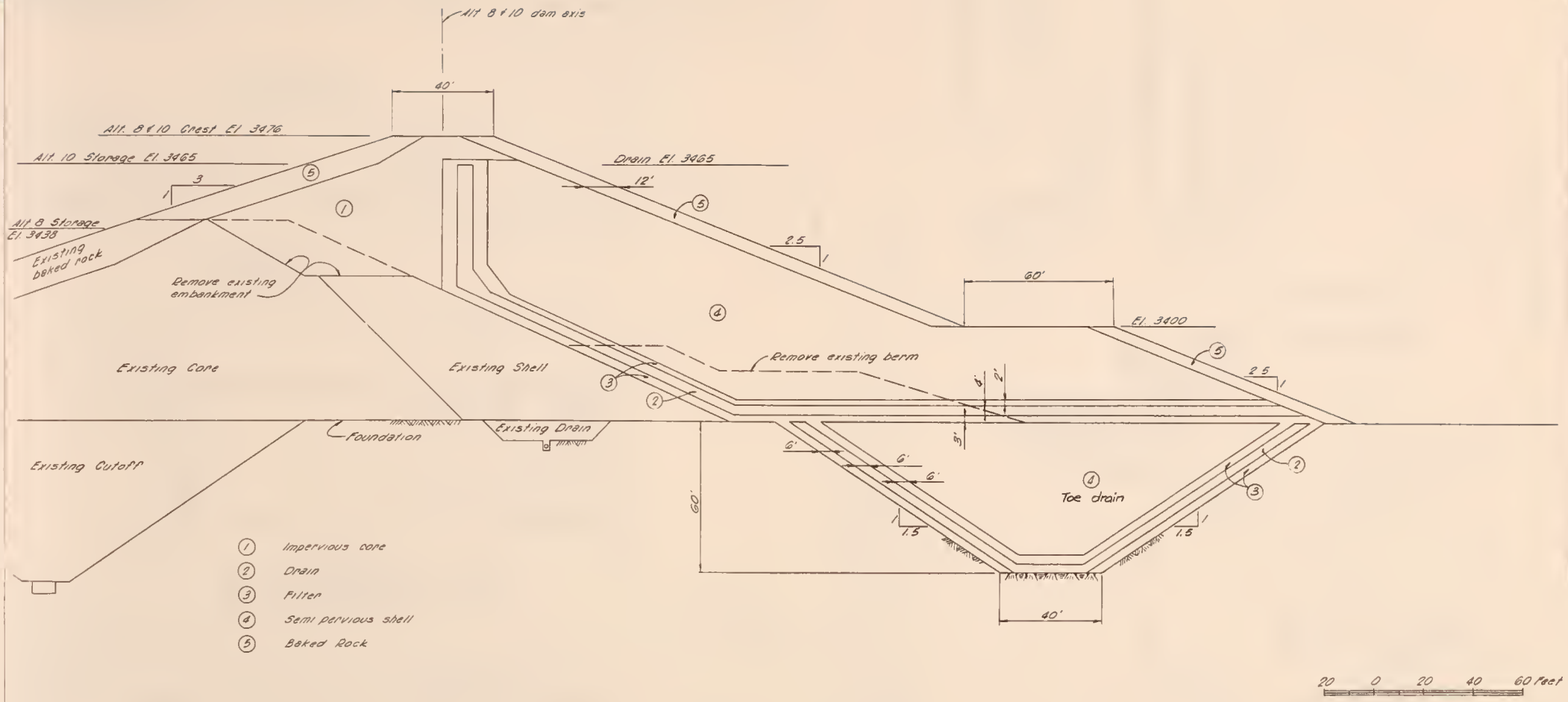
TONGUE RIVER PROJECT
MODIFICATION FEASIBILITY STUDY

STORAGE ELEVATION 3438 AND 3465
EMBANKMENT SECTION

PROJ. NO. 1692	
DRAWN BY RHY	
CHK'D BY RMS	
APP'D BY RCH	
DATE 4/19/77	
SCALE As Shown	

R. C. HARLAN AND ASSOCIATES
65 NEW MONTGOMERY STREET
SAN FRANCISCO, CALIFORNIA 94105
(415) 788-4889

FIGURE
19



ALTERNATIVE 8 AND 10

MONTANA DEPARTMENT OF NATURAL RESOURCES AND CONSERVATION
WATER RESOURCES DIVISION

TONGUE RIVER PROJECT
MODIFICATION FEASIBILITY STUDY

STORAGE ELEVATION 3438 AND 3465
EMBANKMENT SECTION

FILE NO.	169.2
DRAWN BY	RHY / RMS
APP'D BY	RCH
DATE	4/19/77
SCALE	As Shown

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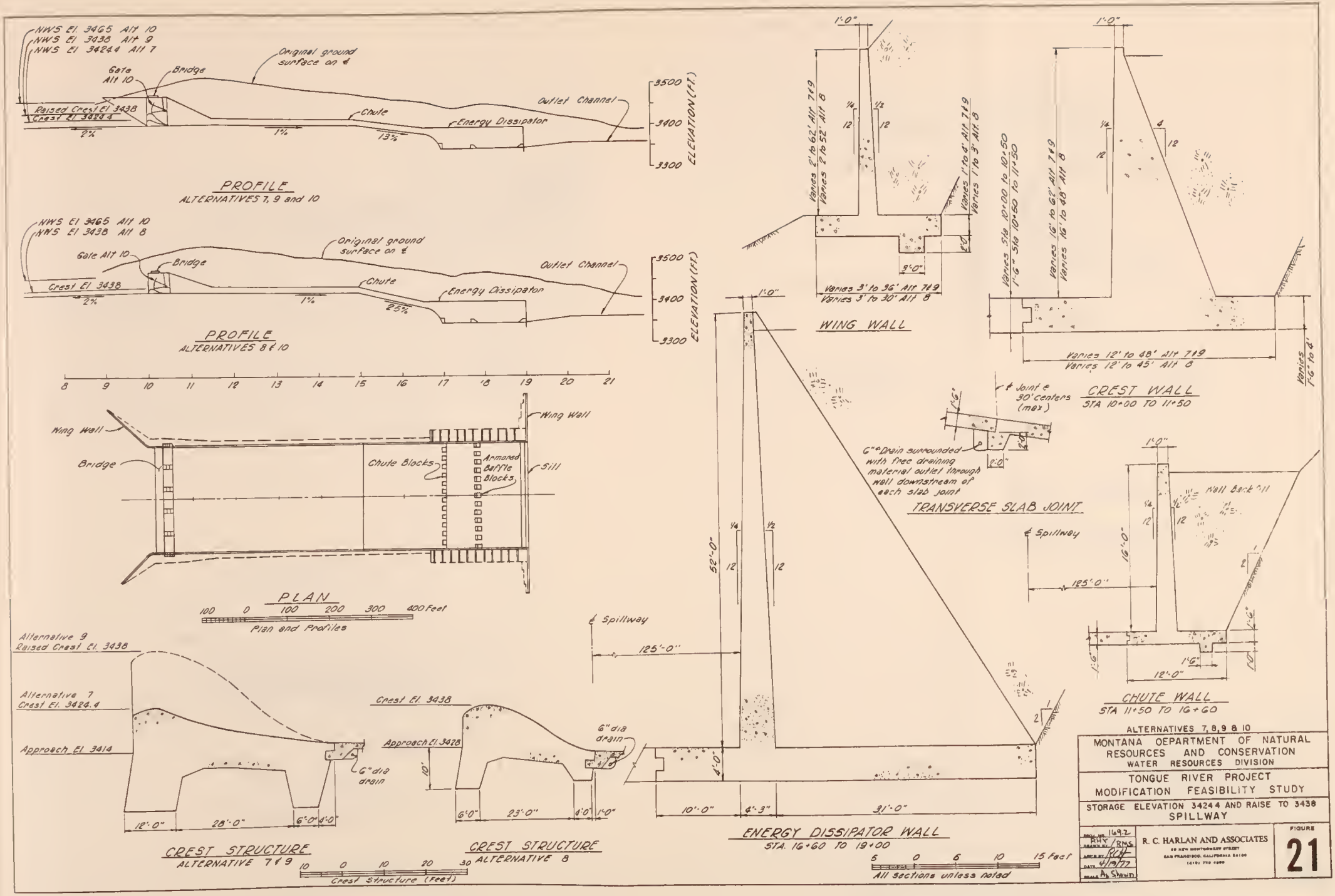
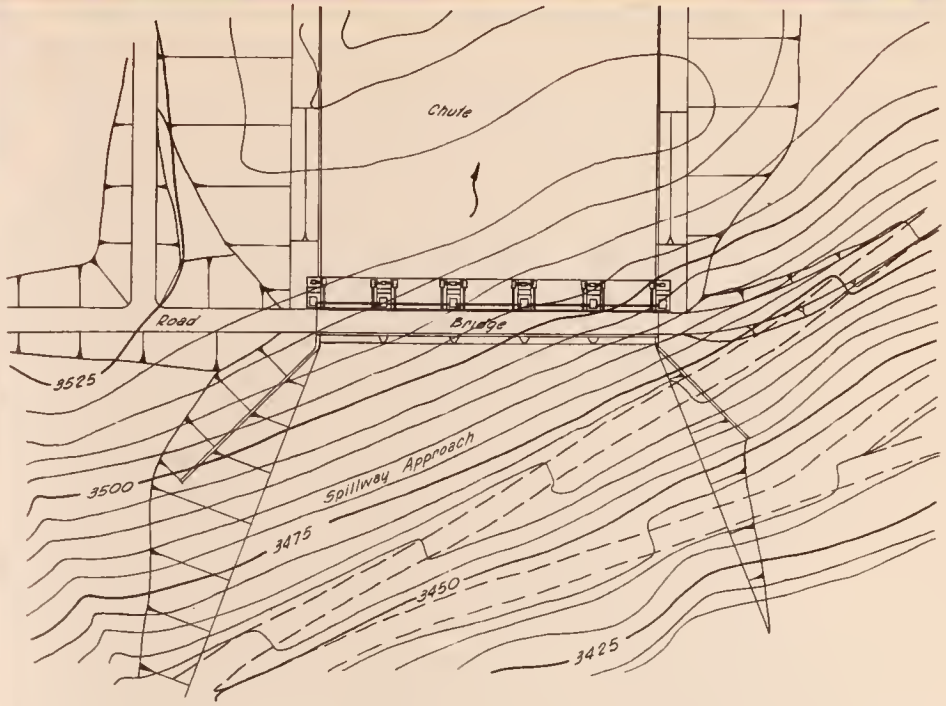
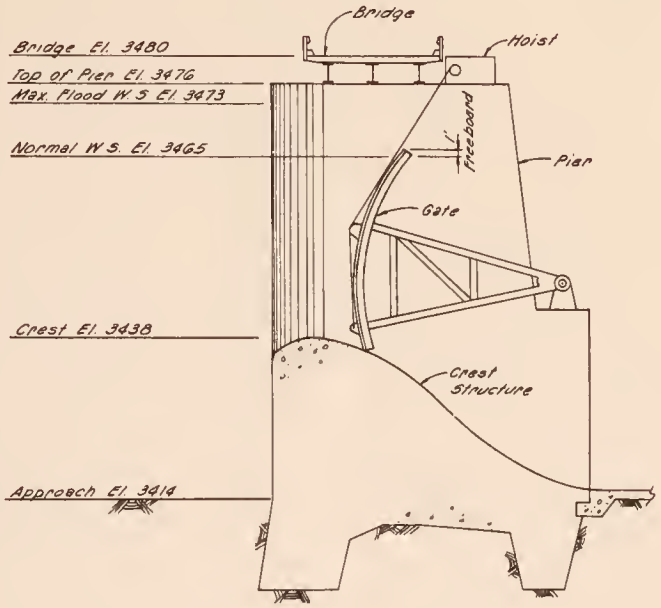
FIGURE 20


NWS El. 3465 Alt 10
NWS El 3438 Alt 9
NWS El 3424.4 Alt 7
Gate Alt 10
Bridge
Original ground surface on ℄
Raised Crest El 3438
Crest El 3424.4
Chute
Energy Dissipator
Outlet Channel
2%
1%
13%
3500
3400
3300
ELEVATION (FT.)
PROFILE
ALTERNATIVES 7, 9 and 10
NWS El 3465 Alt 10
NWS El 3438 Alt 8
Gate Alt 10
Bridge
Original ground surface on ℄
Crest El 3438
Chute
Energy Dissipator
Outlet Channel
2%
1%
25%
3500
3400
3300
ELEVATION (FT.)
PROFILE
ALTERNATIVES 8 & 10
8 9 10 11 12 13 14 15 16 17 18 19 20 21
Wing Wall
Bridge
Chute Blocks
Armored Baffle Blocks
Sill
Wing Wall
PLAN
100 0 100 200 300 400 Feet
Plan and Profiles
Alternative 9
Raised Crest El. 3438
Alternative 7
Crest El. 3424.4
Approach El. 3414
6" dia drain
12'-0"
28'-0"
6'-0"
4'-0"
CREST STRUCTURE
ALTERNATIVE 7 & 9
Crest El. 3438
Approach El. 3428
6" dia drain
10'
6'0"
23'-0"
4'0"
1'-0"
CREST STRUCTURE
ALTERNATIVE 8
10 0 10 20 30
Crest Structure (feet)
1'-0"
Varies 2' to 62' Alt 7 & 9
Varies 2' to 52' Alt 8
Varies 1' to 4' Alt 7 & 9
Varies 1' to 3' Alt 8
1/4
1/2
12
12
6"
3'-0"
Varies 3' to 36' Alt 7 & 9
Varies 3' to 30' Alt 8
WING WALL
1'-0"
Varies 5' to 101'-00 to 101'-50
1'-6" to 5' to 101'-50 to 111'-50
Varies 16' to 62' Alt 7 & 9
Varies 16' to 48' Alt 8
1/4
12
4
12
Varies 12' to 48' Alt 7 & 9
Varies 12' to 45' Alt 8
Varies 1'-6" to 4'
CREST WALL
STA 10+00 TO 11+50
℄ Joint @ 30' centers (max)
1'-6"
6" ø Drain surrounded with free draining material outlet through wall downstream of each slab joint
1'-0"
TRANSVERSE SLAB JOINT
1'-0"
Wall Back Fill
1/4
1/2
12
12
16'-0"
℄ Spillway
125'-0"
1'-6"
1'-6"
1'-0"
12'-0"
CHUTE WALL
STA 11+50 TO 16+60
1'-0"
52'-0"
1/4
1/2
12
12
℄ Spillway
125'-0"
4'-0"
10'-0"
4'-3"
31'-0"
ENERGY DISSIPATOR WALL
STA. 16+60 TO 19+00
5 0 5 10 15 Feet
All sections unless noted
ALTERNATIVES 7, 8, 9 & 10
MONTANA DEPARTMENT OF NATURAL RESOURCES AND CONSERVATION
WATER RESOURCES DIVISION
TONGUE RIVER PROJECT
MODIFICATION FEASIBILITY STUDY
STORAGE ELEVATION 3424.4 AND RAISE TO 3438
SPILLWAY
PROJ. NO. 169.2
DRAWN BY RHY / RMS
APR'D BY RCH
DATE 4/19/77
SCALE As Shown
R. C. HARLAN AND ASSOCIATES
FIGURE
21

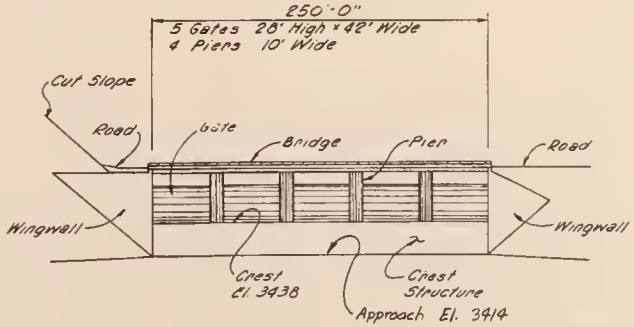


PLAN



TYPICAL SECTION

10 0 10 20 30 Feet



ELEVATION

50 0 50 100 150 Feet

Plan and Elevation

NOTE:
1. Alt 7, 9 & 10 shown. Alt 8 & 10 similar.

ALTERNATIVE 10

MONTANA DEPARTMENT OF NATURAL RESOURCES AND CONSERVATION
WATER RESOURCES DIVISION

TONGUE RIVER PROJECT
MODIFICATION FEASIBILITY STUDY

STORAGE ELEVATION 3465
GATED SPILLWAY CREST

JOB NO. 169.2	R. C. HARLAN AND ASSOCIATES 88 NEW MONTGOMERY STREET SAN FRANCISCO, CALIFORNIA 94105 (415) 788-4988	FIGURE 22
DRAWN BY RMT / RMS		
APP'D BY RCH		
DATE 4/19/77		
SCALE As Shown		

IV COST ESTIMATES

Comparative feasibility cost estimates have been prepared for the various alternatives. A breakdown of quantities and costs is presented on the table following. The basis for the costs of raising the existing dam is a three-year construction period following one year for exploration, design and preparation of plans and specifications. The basis for the updated cost estimate for constructing the new High Tongue River Dam is a four-year construction period following one year of exploration, design and preparation of plans and specifications.

A contingency allowance of 25% is recommended for the raising alternatives and 15% for the High Tongue River Dam. This disparity stems from our experience which indicates there are proportionately more unknowns at the feasibility stage for raising an existing dam than for new construction.

The cost estimates were prepared in the following manner. Since the design for the High Tongue River Dam, Alternative 6, was well developed, the quantity estimates were begun for that alternative immediately upon authorization for the study presented in the October 1976 report. The quantity estimates led directly into the High Tongue River Dam cost estimates while the feasibility modification design data were being developed for the existing Tongue River Dam.

Detailed construction plant, equipment and labor elements were developed and priced. Unit direct construction costs of significant items of work for the High Tongue River Dam were developed and overhead, profit and bond costs added. Using the unit costs developed in detail for the High Tongue River Dam, these units were applied to the quantities developed for the existing Tongue River Dam plans, with appropriate factors used to allow for the disparity in sizes of the projects. Overhead, profit and bond costs were then factored into the key item units and a Comparative Total Project Construction Estimate developed. Allowances for contingencies were then added.

Engineering budgets were developed on the basis of the Comparative Construction Estimates. Fee curves developed by the American Society of Civil Engineers were used. Curve B, for projects of average complexity, was used for High Tongue River Dam. It was assumed that 30% of the fee was preliminary engineering which has already been completed. Curve A, for projects of above average complexity, was used for the alternative modifications to the existing Tongue River Dam. It was considered that only 20% of the basic engineering has been completed in the preliminary work. For each project the basic engineering fee as estimated above was divided two-thirds for design, plans and specifications, and one-third for engineering during construction. A detailed man-month estimate was made for Management of Construction for High Tongue River Dam, based on four, 7 month construction seasons. The percentage of Management of Construction Cost to Comparative Total Project Construction Estimate was developed and used to determine Management of Construction estimates for the other alternatives. Estimates for geotechnical exploration and surveys were also developed for each alternative.

When the supplemental studies for the gated spillway alternatives 7 through 10 were authorized on February 24, 1977, the designs and quantity estimates were begun immediately. Unit prices developed for the other alternatives were established by using appropriate factors to allow for the disparity in size of projects. Gate and hoist estimates were developed separately. Contingency and engineering budgets were developed in the same manner as described above.

Costs not included in the estimates are: land and land rights, State of Montana Administration, environmental investigations and reports, financing and interest and escalation for delay of project beyond 1977. It appears that a delay of some two years will result from making the necessary environmental studies. For each year that the project is delayed beyond 1977, the Total Project Estimate should be multiplied by a factor of 1.07 to 1.10 for escalation-inflation.

	Modify Existing Structures to Storage El. 3424.4
Reservoir Area, Storage - Acres	3,300
Reservoir Area, Flood Pool - Acres	6,700
Reservoir Capacity - Acre Feet	68,000
Firm Yield - Acre Feet Per Year	42,000

	Quantity	Estimated Cost Dollars
DAM EMBANKMENT		
Excavation - Dam Foundation, Drains, Cutoff, Outlet Works	962,100 cu.yds.	$ 3,384,000
Embankment Fill - incl. blankets	1,541,100 cu.yds.	2,754,000
Drilling and Grouting	Lump Sum	264,000
Instrumentation	Lump Sum	120,000
Subtotal Dam Embankment		$ 6,522,000
SPILLWAY		
Excavation and Backfill	2,029,400 cu.yds.*	$ 4,442,000*
Concrete, inc. cement, re-steel, waterstops and included items	43,600 cu.yds.	8,705,000
Drains	7,613 feet	244,000
Bridge	Lump Sum	486,000
Subtotal Spillway		$ 13,877,000*
OUTLET WORKS		
Concrete, incl. cement, re-steel, waterstops and included items	50 cu.yds.	$ 16,000
Steel Conduit		-0-
Outlet Valves, Operating System		-0-
Air Inlet pipe, manifold and bridge	Lump Sum	91,000
Bypass Pumping	Lump Sum	278,000
Subtotal Outlet Works		$ 385,000
ROADS AND SITE WORK		
Road Relocation	-0- miles	-0-
Road Improvement	10 miles	$ 1,189,000
Site Work	Lump Sum	19,000
Subtotal Roads and Site Work		$ 1,208,000
COMPARATIVE TOTAL PROJECT CONSTRUCTION ESTIMATE		$ 21,992,000*
ALLOWANCE FOR CONTINGENCIES		$ 5,498,000*
ENGINEERING		
Geotechnical Investigation and Surveying		$ 195,000
Design Engineering, Plans and Specifications		690,000*
Engineering during Construction, Management of Construction		1,737,000*
Subtotal Engineering		$ 2,622,000*
COMPARATIVE TOTAL PROJECT ESTIMATE		$ 30,112,000*

*REVISED FROM OCTOBER 1976 REPORT

Additional items not included which must be added to this estimate include land and land rights, State of Montana Administrative costs, Environmental Investigations and Reports, interest and costs of financing and escalation to beginning of project.

2		3		4	
Modify Existing Reservoir to Storage El. 3438		Modify Existing Reservoir to Storage El. 3465		Raise Existing Reservoir from Modified 3424.4 to 3438	
5,000		8,400		5,000	
8,100		10,400		8,000	
130,000		320,000		130,000	
67,500		100,000		67,500	
Quantity	Estimated Cost Dollars	Quantity	Estimated Cost Dollars	Quantity	Estimated Cost Dollars
1,159,100 cu.yds.	$ 3,787,000	1,159,100 cu.yds.	$ 3,769,000	125,000 cu.yds.	$ 321,000
2,056,100 cu.yds.	3,739,000	3,376,100 cu.yds.	4,924,000	441,000 cu.yds	1,067,000
Lump Sum	264,000	Lump Sum	264,000	Lump Sum	7,000
Lump Sum	140,000	Lump Sum	170,000	Lump Sum	20,000
	$ 7,930,000		$ 9,127,000		$ 1,415,000
1,828,400 cu.yds.*	$ 4,019,000*	1,634,400 cu.yds.*	$ 3,607,000*	4,000 cu.yds.	$ 16,000
45,900 cu.yds.	9,146,000	39,300 cu.yds.	7,843,000	4,800 cu.yds.	1,169,000
7,613 feet	244,000	7,613 feet	244,000	-0- feet	-0-
Lump Sum	486,000	Lump Sum	486,000	Lump Sum	-0-
	$ 13,895,000*		$ 12,180,000*		$ 1,185,000
136 cu.yds.	$ 140,000	1,250 cu.yds.	$ 738,000	Lump Sum	$ 116,000
	-0-		-0-		-0-
	-0-		-0-		-0-
Lump Sum	91,000	Lump Sum	160,000	Lump Sum	-0-
Lump Sum	278,000	Lump Sum	278,000	Lump Sum	-0-
	$ 509,000		$ 1,176,000		$ 116,000
5 miles	$ 1,485,000	6 miles	$ 1,777,000	5 miles	$ 1,393,000
5 miles	594,000	4 miles	474,000	0 miles	-0-
Lump Sum	23,000	Lump Sum	35,000	Lump Sum	10,000
	$ 2,102,000		$ 2,286,000		$ 1,403,000
	$ 24,436,000*		$ 24,769,000*		$ 4,119,000
	$ 6,109,000*		$ 6,192,000*		$ 1,023,000
	$ 195,000		$ 195,000		$ 25,000
	767,000*		777,000*		177,000
	1,930,000*		1,957,000*		351,000
	$ 2,892,000*		$ 2,929,000*		$ 553,000
	$ 33,437,000*		$ 33,890,000*		$ 5,695,000

5 Raise Existing Reservoir from Modified 3438 to 3465		6 High Tongue River Dam Storage El. 3438		7 Modify Existing Structures to Storage El. 3424.4 with future gate provisions	
8,400		7,700		3456	
10,400		11,200		3,300	
320,000		320,000		6,700	
100,000		100,000		68,000	
				42,000	
Quantity	Estimated Cost Dollars	Quantity	Estimated Cost Dollars	Quantity	Estimated Cost Dollars
131,000 cu.yds.	$ 331,000	2,880,000 cu.yds.	$ 8,606,000	1,130,100 cu. yds.	$ 3,758,000
1,123,000 cu.yds.	2,544,000	11,000,600 cu.yds.	17,307,000	1,909,100 cu. yds.	3,216,000
Lump Sum	13,000	80,500 feet	1,632,000	Lump Sum	264,000
Lump Sum	30,000	Lump Sum	211,000	Lump Sum	120,000
	$ 2,918,000		$ 27,756,000		$ 7,358,000
				2,036,400 cu. yds.	$ 4,556,000
5,000 cu.yds.	$ 19,000	3,096,500 cu.yds.	$ 6,818,000		
				52,100 cu. yds.	10,362,000
10,900 cu.yds.	2,530,000	56,400 cu.yds.	10,521,000	7,613 feet	244,000
-0- feet	-0-	10,150 feet	668,000	Lump Sum	390,000
Lump Sum	-0-	Lump Sum	394,000		$ 15,552,000
	$ 2,549,000		$ 18,401,000		
				60 cu. yds	$ 19,000
1,137 cu.yds.	$ 509,000	14,700 cu.yds.	$ 2,643,000		-0-
	-0-	932,000 lbs.	1,115,000		-0-
	-0-			Lump Sum	91,000
Lump Sum	65,000			Lump Sum	278,000
Lump Sum	-0-	Lump Sum	646,000		$ 388,000
	$ 574,000		$ 4,404,000		
				6 miles	$ 1,777,000
1 mile	$ 278,000	-0- miles	$ -0-	4 miles	474,000
0 miles	-0-	1 mile	212,000	Lump Sum	35,000
Lump Sum	20,000	Lump Sum	47,000		$ 2,286,000
	$. 298,000		$ 259,000		
	$ 6,339,000		$ 50,820,000		$ 25,584,000
					$ 6,396,000
	$ 1,585,000		$ 7,623,000		
					$ 195,000
	$ 25,000		$ 130,000		803,000
	266,000		1,118,000		2,021,000
	536,000		3,810,000		
					$ 3,019,000
	$ 827,000		$ 5,058,000		
					$ 34,999,000
	$ 8,751,000		$ 63,501,000		

8		9		10	
Modify Existing Reservoir to Storage El. 3438 with future gate provisions		Raise Existing Reservoir From Modified 3424.4 to 3438 with Provision for Future Gates		Raise Existing Reservoir From Modified 3438 to 3465 by Provision of Gates	
3476 5,000 8,100 130,000 67,500		3476 5,000 8,000 130,000 67,500		3476 8,400 9,300 320,000 100,000	
Quantity	Estimated Cost Dollars	Quantity	Cost Dollars	Quantity	Cost Dollars
1,186,100 cu. yds.	$ 3,833,000	145,000 cu. yds.	$ 295,000		
2,615,100 cu. yds.	4,420,000	800,000 cu. yds	1,875,000		
Lump Sum	264,000	Lump Sum	7,000		
Lump Sum	155,000	Lump Sum	20,000		
	$ 8,672,000		$ 2,197,000		-0-
1,830,400 cu. yds.	$ 4,088,000	-0-	-0-	Furnish Gates	$ 721,000
				Furnish Hoists	225,000
44,700 cu. yds.	8,921,000	-0-	-0-	Install Gates & Hoists	260,000
7,613 feet	244,000	-0-	-0-		
Lump Sum	390,000	-0-	-0-		$ 1,206,000
	$ 13,643,000				
190 cu. yds.	$ 196,000	272 cu. yds.	$ 280,000		
	-0-		-0-		
	-0-		-0-		
Lump Sum	121,000	Lump Sum	30,000		
Lump Sum	278,000	Lump Sum	-0-		
	$ 595,000		$ 310,000		-0-
6 miles	1,777,000		-0-		
4 miles	474,000		-0-		
Lump Sum	35,000		-0-		
	$ 2,286,000		-0-		
	$ 25,196,000		$ 2,507,000		$ 1,206,000
	$ 6,299,000		$ 627,000		$ 302,000
	$ 195,000		$ 25,000		$ -0-
	791,000		107,000		120,000
	1,990,000		213,000		25,000
	$ 2,976,000		$ 345,000		$ 145,000
	$ 34,471,000		$ 3,479,000		$ 1,653,000

V RECOMMENDATIONS FOR FURTHER STUDY

These studies were limited in scope to provide only sufficient data for comparison among all alternatives. The cost estimates in this summary report are considered to be comparable and adequate for selection of the proper alternative among the ten presented. Some further optimization of alternatives will probably be required before final design is begun. A staged development should be planned wherein the water storage elevation would be raised to the maximum permissable level without forcing flood waters onto the adjacent coal mining operations, along with a spillway designed for simple future raising to Elev. 3438 with provisions for ultimately adding crest gates to raise the dam storage elevation to 3465. Explorations should be carried out to determine the optimum location for the spillway and to determine whether relief wells can be used as an alternative to the massive toe drain. Land requirements should be studied relative to the adjacent coal mining operations and flood water levels.

When the project design is implemented, the following items should also be studied further:

1. Installation of a small hydroelectric plant to provide sale of electric power to offset project costs.
2. An accurate firm yield study based on a specific project configuration.
3. Estimate of evaporation and seepage losses from the enlarged reservoir.
4. Determine current active storage and updated siltation rates for the reservoir.
5. Further observation and study of outlet works performance and possible modifications.
6. Detailed subsurface, geotechnical explorations and testing.
7. Specific construction materials investigation including concrete aggregates and embankment filter and drain materials.
8. Review of storm hydrology.
9. Perform study of filling rates as related to financing and scheduling analysis.

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